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# A PRELIMINARY SHEAR VELOCITY MODEL FOR CENTRAL ASIA

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Waveforms of S body waves and Rayleigh waves are analysed with the method of partitioned waveform inversion, with the objective to develop a three-dimensional S-velocity model for the crust and upper mantle below Central Asia. Thus far, $10^3$ seismograms have been processed. Using starting models with crustal thicknesses representative for the source-receiver path, good predictions of the observed waveforms, and good fits, have been obtained. The preliminary model, constructed on the basis of the data collected, shows that the Indian craton is marked by distinctly higher velocities than the rest of the region between 45 and at least 100 km depth. The Tarim craton and the Sino-Korean craton do not show high velocities at this depth. The Tibetan Plateau shows low velocities between 70 and 200 km depth.

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## A PRELIMINARY SHEAR VELOCITY MODEL FOR CENTRAL ASIA

### Objective

The objective of this study is to develop a three-dimensional (3-D) shear wave velocity model for the Upper Mantle below Central and East Asia. Such a velocity model will be useful for discriminating nuclear explosions from natural earthquakes through signal analysis techniques. Furthermore, it can provide insight in the tectonic history of the region.

A large amount of digital data are available for the region from the regional broad-band and long-period stations of several networks (GSN, CDSN, Geoscope, PASSCAL). The distribution of seismicity and stations provides a data set of seismograms that samples the region densely and that holds great potential for analysing the data in terms of a 3-D model.

### Data inversion

We apply the waveform analysis technique that was developed by Nolet (1990). This approach uses waveforms of S-waves and Rayleigh waves to develop a 3-D velocity model. First, the individual seismograms are inverted for path integrals of the velocity along the source-receiver path, using methods of nonlinear optimization. Synthetic seismograms are constructed by mode summation. Errors are determined for the path integrals, and subsequently they are transformed into a set of uncorrelated linear constraints on the velocity profile between source and receiver. Second, all linear constraints, associated to different source-receiver combinations, are combined in a linear inversion for a 3-D model. A previous application of the method to derive a model for the Upper Mantle below Europe (Zielhuis and Nolet, acc for publ.) showed that by using relatively short paths and high frequencies (up to 60 milliHz for body waves; up to 25 milliHz for surface waves) a lateral resolution of about 200 km can be obtained locally.

The crust in Central and East Asia shows spectacular variations in thickness. The Tibetan Plateau is marked by an extremely thick crust of 70 km, while parts of the Indian craton have a 25 km thick crust. Crustal thickness variations of this size have a large influence on the waveforms. Ignoring these variations in the inversion can result either in the impossibility to fit the waveforms, or in mapping of the crustal thickness variations as velocity variations in the model. To avoid the

latter as much as possible, We constructed a set of starting models with crustal thickness ranging from 25 to 70 km, in steps of 5 km. On the basis of the crustal thickness information from the map of Kunin et al. (1987), and the digitized version by Fielding et al. (1992), we are able to produce satisfying predictions of the observed waveforms, and good fits, with this set of starting models. For wavepaths with large crustal thickness variations we usually obtain good predictions and fits to the waveforms taking a starting model with crustal thickness equal to the average along the wavepath. Apart from a direct influence on the waveform, crustal thickness variations can also cause multipathing and scattering for waves at certain frequencies. Comparison of the predicted waveforms of the fundamental mode with the observations shows that for many records the waveforms become slightly distorted above 20mHz, which suggests that these effects occur at somewhat lower frequencies for this region than for Europe. In general we low-passed the fundamental mode at 20 or 15mHz. The waveforms of the S body waves seem to be less influenced by the crustal thickness variations along the great circle path, but they are sensitive to crustal structure near the source and receiver. We allow for differences in crustal thickness of source-, path-, and receiver location by taking different starting models to compute the excitation of the modes. In this way we are able to produce good fits to the body waves for frequencies up to 50mHz. As an example figure 1 shows the fits for the records of an earthquake in the Tadzhikistan-Xinjiang border region on 29 March 1990.

**Preliminary model**

Thus far, 103 seismograms, recorded at GSN, CDSN, and Geoscope stations, have been inverted. Figure 2 shows the wavepaths associated with these records. The linear constraints on the velocity for these wavepaths have been combined in a damped linear inversion. Computation of the wavefroms predicted by the 3-D model and comparison with the observations will be postponed until enough data have been processed to obtain a good resolution. Figure 3a-d show several constant depth slices through the result. The model is represented as velocity perturbations against a reference model with a 45 km thick crust. There are a few interesting features in this preliminary result. The Indian craton shows distinct high velocities from 45 km to at least 100 km depth. Below that velocities are still slightly higher than the reference. The Central Tibetan Plateau has low velocities at 100 and 200 km depth. Just below the 400 km discontinuity, a zone of low velocities stretches from the eastern Tibetan Plateau to the northwest. In contrast to the Indian craton, the Tarim craton does not show high velocities at 100 km depth and neither does the Sino-Korean craton. South of the Pamirs and Hindu

Kush, a high velocity anomaly is located between 100 and 300 km depth. Another high velocity anomaly is located north of the Eastern Tibet, between 100 and 200 km depth.

## Conclusions and recommendations

A preliminary selection of 103 seismograms recorded at stations of the GSN, CDSN, and Geoscope networks has been analysed with the method of partitioned waveform inversion. Using starting models with crustal thicknesses that are representative for the particular source-receiver minor arcs, in general good predictions for the observed waveforms and good fits were obtained. There are interesting features in the preliminary model, and the plan is to invert much more data from the extensive data set that is available in order to improve the resolution. For the Tibetan Plateau in particular, it will be interesting to concentrate on short period Rayleigh waves recorded at epicentral distances of a few hundred km because this will improve the resolution in the crust and uppermost mantle. This will hopefully reveal whether the low velocities at 100 and 200 km depth in the present model are caused by the thick crust on the Plateau and lack of vertical resolution.

## References

Fielding, E., Barazangi, M., and B.L. Isacks, A geological and geophysical information system for Eurasia, *Semiannual Technical Report No 3*, Phillips Laboratory., Hanscom AFB, MA, 1993.

Kunin, N. et al., Map of depth to Moho and Map of depth to seismic basement, Institute of Physics of the Earth, Moscow, 1:15,000,000 scale, 1978.

Nolet, G., Partitioned waveform inversion and two-dimensional structure under the Network of Autonomously Recording Seismographs, *J. Geophys. Res.*, **95**,, 8499-8512, 1990

Zielhuis, A. and G. Nolet, Shear wave velocity variations in the upper mantle below Central Europe, *Geophys. J. Int.*, acc. for publ.

Figure 1a

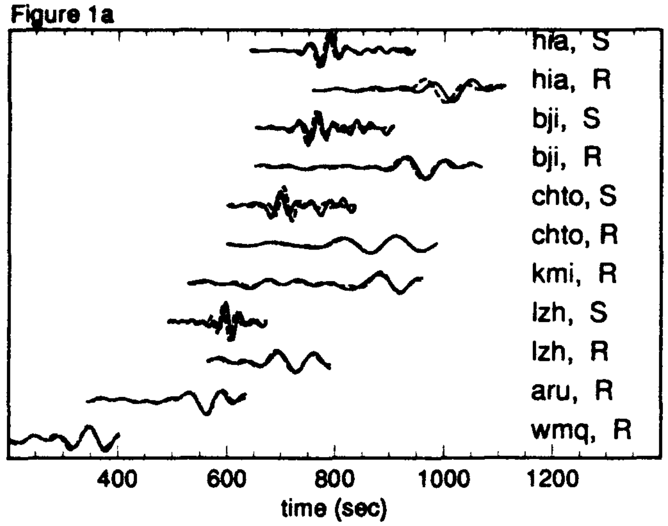



Figure 1b

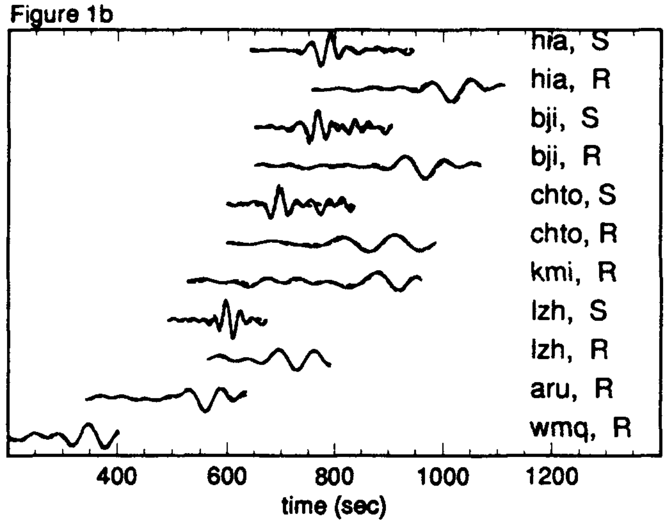



Figure 1
Waveform fits for the records of the earthquake in the Tadzhikistan-Xinjiang border region on March 1990.
1a: For each station, a time window containing the fundamental mode of the Rayleigh wave (R; lowpassed at 15 or 20 mHz) is displayed. A separate window contains the S wave (if it is a clear arrival), lowpassed at 50 or 60 mHz. Solid lines represent the observed waveform, dashed lines the best initial prediction by a 1-D starting model.
1b: Fits after inversion for path integrals of the velocity along the source-receiver path.

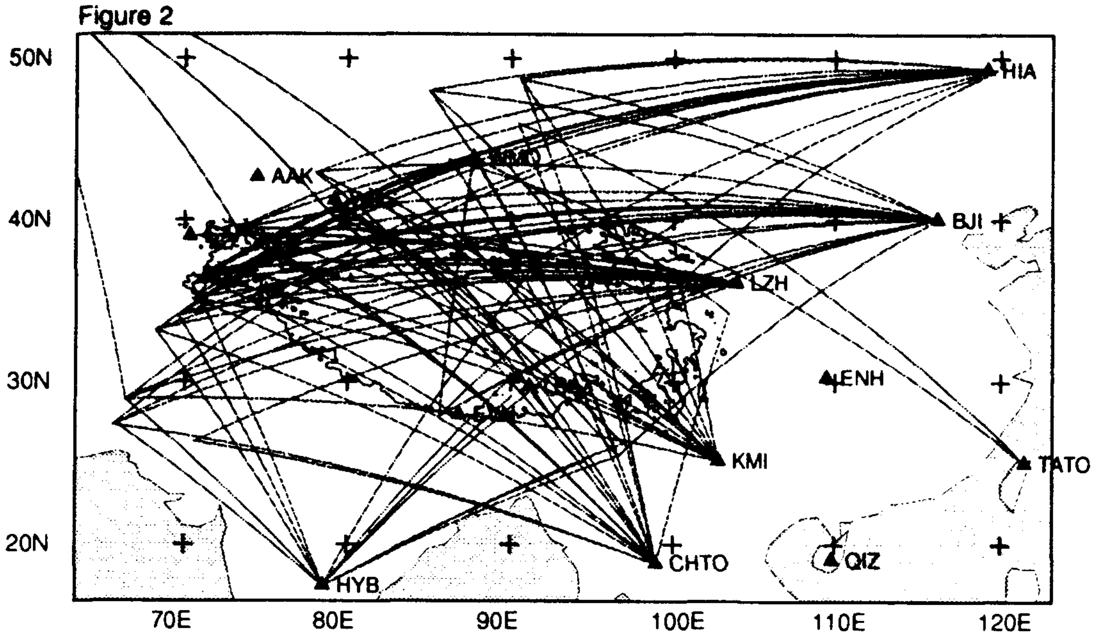
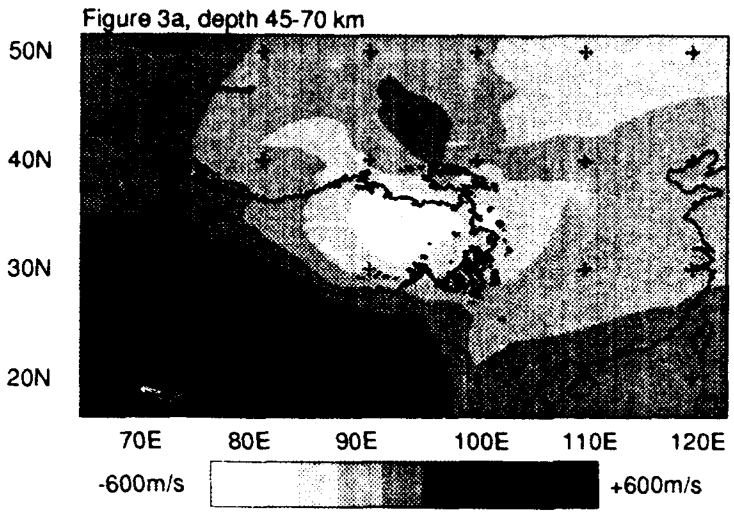



Figure 2
Wave paths associated with the 103 seismograms that have been processed so far. Triangles indicate the station locations.



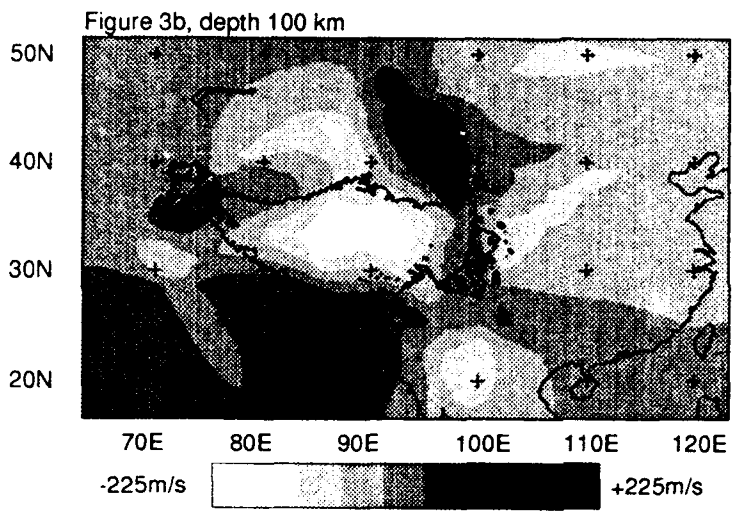
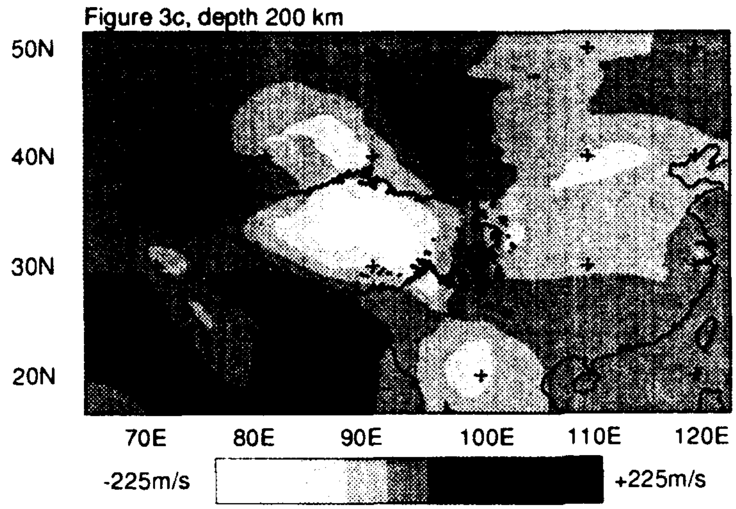




Figure 3
Constant depth slices through the preliminary 3-D S-velocity model. The model is presented as velocity perturbations against a reference model with a 45 km thick crust. The anomalies are contoured according to the legend.
3a: Velocity perturbations between 45 and 70 km depth. Reference velocity is 4.47km/s. This layer represents the lower crust below the Tibetan Plateau, and upper mantle for most of the rest of the region. The velocity perturbations are much larger than for the other depth slices (see legends).
3b: Velocity perturbations at 100 km depth. Reference velocity is 4.5km/s.



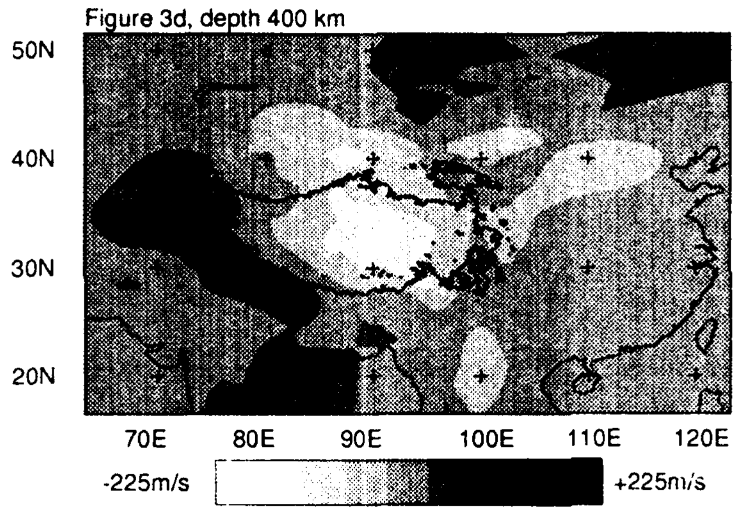




Figure 3 (continued)

3c: Velocity perturbations at 200 km depth. Reference velocity is 4.5km/s.

3d: Velocity perturbations at 400 km depth, just below the 400 km discontinuity. Reference velocity is 4.933km/s.